

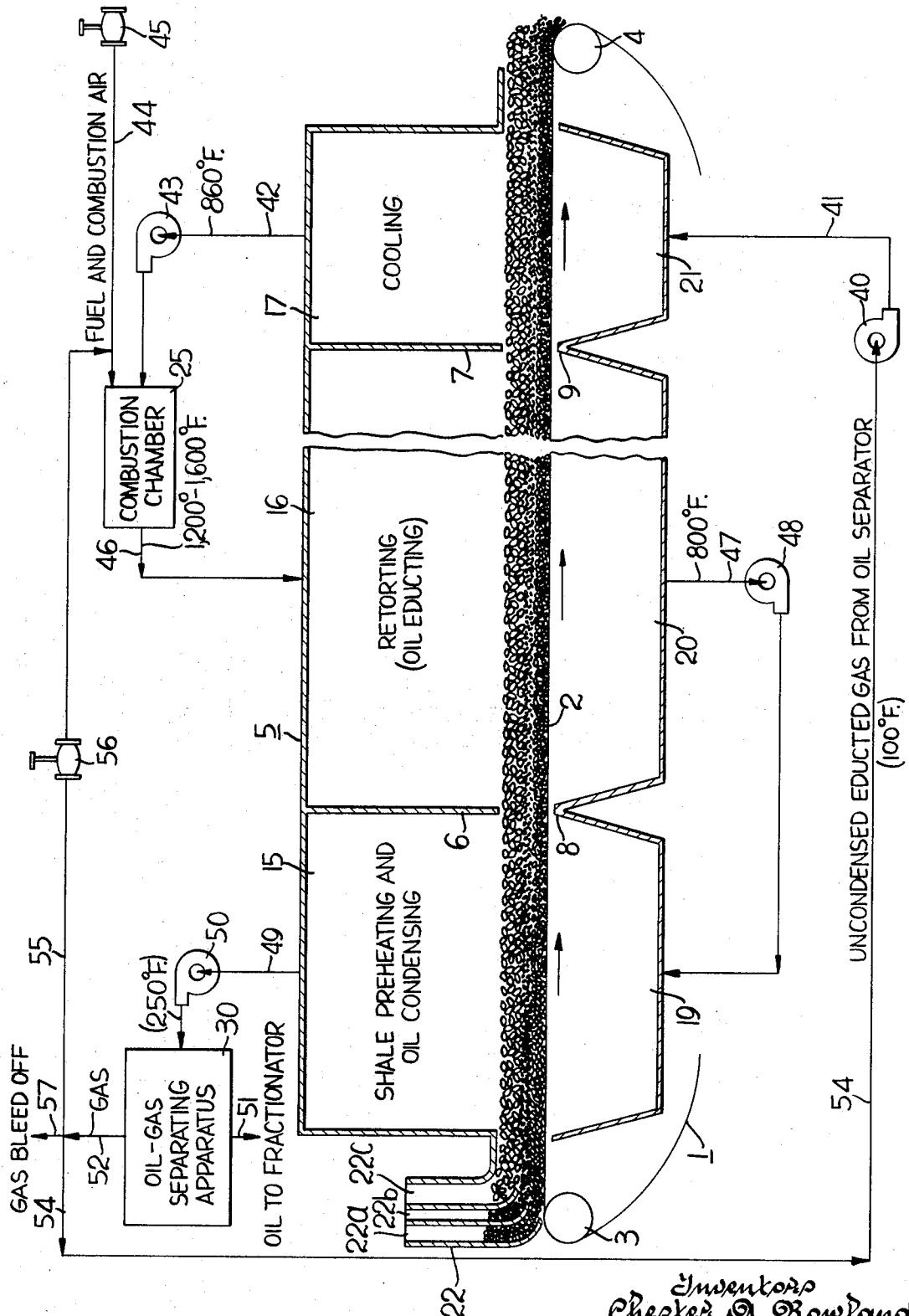
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C. A. ROWLAND ET AL

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TRAVELING GRATE METHOD FOR THE RECOVERY OF OIL FROM SHALE

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Inventors
 Chester A. Rowland
 Robert W. Frump
 By *Arthur M. Strick*
 Attorneys

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3,560,368 TRAVELING GRATE METHOD FOR THE RECOVERY OF OIL FROM SHALE

Chester A. Rowland, Shorewood, and Robert D. Frans,
Brookfield, Wis., assignors to Allis-Chalmers Manu-
facturing Company, Milwaukee, Wis.

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ABSTRACT OF THE DISCLOSURE

A method is disclosed for recovering oil from oil bearing shale rock in which the rock is screened to provide three size fractions, large size, intermediate size and small size. The large size need have no upper size limit but may, for example, be screened to plus 1 inch minus 1½ inch. The intermediate size may be plus ¾ inch minus 1 inch; and the small size plus ¼ inch minus ⅝ inch. Such size fractions are deposited on a traveling grate in a segregated bed with the large size on top, the intermediate size on the bottom and the small size therebetween. The traveling grate carries this bed through a preheating zone where moderately heated gases (from a retorting zone such as will be described) pass upwardly through the bed and then the bed passes through a retorting zone where oil is educted from the shale by highly heated gases passing downward through the bed. In the

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to cross-flow transfer of mass and heat between particulate material and heated gases such as may be applied, for example, to processes and apparatus for the recovery of oil from carbonaceous materials including oil shale of the character found in the State of Colorado. In particular, this invention is directed to a method of arranging particles of a material such as shale on an apparatus of the horizontal traveling grate type, and passing gases therethrough in a path transverse to the path of material movement.

Description of the prior art

United States Bureau of Mines Bulletin 635 published in 1966 states that 53 companies were producing oil from coal and shale in 1860 but the discovery of liquid oil in the United States in 1859 soon ended that industry in the United States. This bulletin tells about the rapid rise in consumption of petroleum products that eventually resulted in a revived interest in searching for an oil shale retorting system that would be satisfactory from a standpoint of economics, operability and the character of oil produced.

The Bureau of Mines bulletin states that oil shale retorts may be divided into four general classes based on the method of heat application:

Class	Method of heat application	Examples
I.....	Heat is transferred to the shale through a wall.....	Pumpherson Hayes, Berg.
II.....	Heat is transferred to the shale from the combustion occurring in the retort by burning product gases and the residual carbon in the retorted shale.	N-T-U, Union Oil Co., Pintsch, Bureau of Mines gas-combustion.
III.....	Heat is transferred to the shale by passing previously heated gases or liquids through the shale bed.	Swedish Industrial, Bureau of Mines gas-flow, Royster.
IV.....	Heat is transferred to the shale by introduction of hot solids into the retorting bed.	Standard Oil Co. fluidized bed, Bureau of Mines hot-solids-contact, Aspeco, TOSCO.

retorting zone the bottom layer of intermediate size particles prevents the smallest particles falling through or plugging gas passages in the grate while the largest and most difficult to process particles make first contact with gases that are the hottest and contain the least amount of educted oil, for maximum temperature and mass (i.e., oil) transfer therebetween, and these largest particles shield the smallest particles from the highest temperature of the gases in the retorting zone to prevent the smallest particles adhering together in a manner that would destroy the gas permeability of the bed on the grate. In the preheating and condensing zone the top layer of the largest particles provides a barrier against fine particles escaping with the gas stream containing oil mist.

CROSS-REFERENCE TO RELATED PATENT APPLICATION

This application relates to a method which can be performed utilizing apparatus disclosed and claimed in the following copending United States patent applications: Ralph W. Weggel and William A. Blann, Ser. No. 686,038, filed Nov. 28, 1967, now abandoned and refiled May 11, 1970 as a continuation application Ser. No. 56,037 and entitled "Process and Apparatus for the Recovery of Oil from Shale by Indirect Heating"; Robert D. Frans, Ser. No. 699,430, filed Jan. 22, 1968, and entitled "Method and Apparatus for the Recovery of Oil from Shale by Indirect Heating"; and Robert D. Frans, Ser. No. 705,989, filed Feb. 16, 1968, and entitled "Method and Apparatus for the Recovery of Oil from Shale by Gases of Fuel Burned External Thereof"; and is related to further improvements to the method-process concepts disclosed and claimed therein.

Further information relating to these prior art systems may be found in the Bulletin and references cited therein.

An index of patents, issued by the United States and other nations, relating to the mining and retorting of oil shale and the recovery of its products, has been published by the United States Bureau of Mines as Bulletin 468, in 1948 (650 pages). A three part supplement identified as Bulletin 574 was published in 1958 (Part I, 134 pages; Part II, 75 pages; and, Part III, 62 pages).

As will be explained later, the methods of the present invention may be applied to Class II and Class III systems for operation with an apparatus including a horizontal traveling grate. Certain of prior art patents including some related to fields other than oil shale, provide disclosures useful in describing the evolution of the present invention and these will now be specifically discussed.

The evolution of horizontal traveling grates in the field of retorting oil shale may be illustrated by reference to a few patents, such as U.S. 1,317,514 of 1919; British Pats. 278,694 and 278,740 of 1928; U.S. 2,269,025 of 1942; and, U.S. 3,325,395 of 1967. Of these patents only U.S. 3,325,395 suggests forming a bed of shale particles in three layers, segregated according to size.

Prior to U.S. 3,325,395, however, attention was directed to multilayer beds of unburned particles of the same material segregated according to size, in fields other than retorting shale. In the field of sintering mineral ores, two horizontally arranged layers of the same unburned material, but of different size particles, to form a bed in a traveling grate was suggested, for example, in U.S. 3,076,248 of 1963. Three layer beds, which are of more interest with regard to the present invention, were suggested in other fields prior to the oil shale Pat. U.S. 3,325,395, in such patents as U.S. 1,926,032 of 1933; U.S.

3,042,390 of 1962; and, U.S. 3,166,403 of 1965. In the field of sintering iron ore it has been suggested to form beds on traveling grates with four to eight layers, as for example in patents U.S. 2,862,807 of 1968 and U.S. 3,024,101 of 1962.

All of the aforementioned prior art patents, while helpful to understand the evolution of the technology, suggest bed formations on traveling grates with particle size arrangements, and for purposes, different than are involved in the present invention and that will hereinafter be described.

SUMMARY OF THE INVENTION

The objects of the present invention are directed to a search for a method and apparatus for the recovery of oil from oil bearing material, which is satisfactory from the standpoints of economics, operability, and character of the oil recovered; and to achieve to the greatest extent possible nine requirements that have been defined by the United States Bureau of Mines and set forth in Bulletin 635 (page 6). The nine requirements for a desirable system there set forth are the following:

- (1) It should be continuous.
- (2) It should have a high feed rate for unit cross sectional area.
- (3) It should have high oil recovery efficiency.
- (4) It should require a low capital investment, and possess a high operating time factor with low operating costs.
- (5) It should be thermally self-sufficient; that is, all heat and energy requirements should be supplied without burning any of the product oil.
- (6) It should be amenable to enlargement into high-tonnage retorts rather than to a multiplicity of small units.
- (7) It should require little or no water because the Green River oil shale deposits are located in an arid region of the State of Colorado.
- (8) It should be capable of efficiently processing oil shale of a reasonable wide range of particle sizes to minimize crushing and screening.
- (9) It should be mechanically simple, easily operable.

Still another object of the present invention is to provide an improved method of operating a horizontal traveling grate furnace to heat a bed of particulate material on the grate with a flow of hot gases and utilize small size particles of the material by arranging the particles in the bed according to size with the small size between a layer of intermediate size particles and a layer of larger particles, to prevent the small particles falling through or plugging the grate and to shield the small particles from the most intense heat that might otherwise fuse the small particles and inhibit the flow of heating gases through the bed.

In the following description of how these objects are attained, and claims related thereto, a stream of gases will be referred to as a noncondensable combustible gas stream, either oxygen free or mixed with combustion air. By this terminology it is meant gases such as are driven from shale rock heated in an oxygen free atmosphere and these gases are a mixture of carbonaceous gases including light hydrocarbon fractions, hydrogen, nitrogen and other gases in trace amounts. By referring to such a gas stream as being noncondensable, it is meant that the gas stream cannot be condensed, as a practical matter, with equipment and in environments such as are herein disclosed or found in oil refineries; and that these gases are therefore of a character similar to those produced by oil refining operations which are burned at the refinery to dispose of them safely.

According to one practice of the present invention as applied to the retorting of oil bearing shale rock on a horizontal grate, the shale is crushed and screened to provide three size fractions including a large size of plus 1 inch minus 1½ inch, an intermediate size plus ⅝ inch minus 1 inch, and a small size plus ¼ inch minus ⅜

inch. These size fractions are arranged on the grate with the intermediate size particles forming a bottom layer, the smallest particles forming a second layer, and the largest particles forming a top layer covering the smallest particles. This bed of material may then be transported through a material preheating and oil condensing zone; a retorting zone where oil is educted from the shale; and a cooling zone. A stream of oxygen free combustible gas, the source of which will be explained later, is preheated by passing through shale in the cooling zone. The preheated gas is delivered to a combustion chamber where a controlled amount of combustion air is mixed with the preheated gas (and if desired an additional nonpreheated quantity of the gas stream for added temperature control purposes) in such quantities as are necessary to provide for combustion that provides an oxygen free gas stream at about 1200° to 1600° F. The oxygen free combustion gases at about 1200° to 1600° F. then pass downwardly through the shale in the retorting zone to educt oil and quantities of the noncondensable oxygen free combustible stream of gases from the shale, and then upwardly through the shale in the material preheating and oil condensing zone where the educted oil is condensed and becomes suspended as a stable mist in the oxygen free noncondensable combustible gas stream from which the oil may be mechanically separated. This gas stream, after the oil is separated therefrom provides the gas stream, previously referred to, that cools spent shale and is thereafter partially burned remote from the retorting zone to efficiently utilize this fuel heat source to the extent necessary to provide the desired oxygen free gas stream at 1200° to 1600° F.

Other features and objects of the invention that have been attained will appear from the more detailed description to follow with reference to an embodiment of the present invention.

BRIEF DESCRIPTION OF THE DRAWING

The accompanying drawing shows diagrammatically an apparatus to which the method of the present invention may be applied including a traveling grate shown in side elevation and in section.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawing, a gas permeable traveling grate assembly 1 defines a loop with an upper strand 2 supported between head and tail shafts 3 and 4 for movement in a generally horizontal path in the direction indicated by arrows. A housing assembly 5 is arranged below and over the upper strand 2 and baffles 6, 7 above strand 2 and baffles 8, 9 below strand 2 divide the interior of the housing assembly 5 into at least three chambers 15, 16 and 17 above strand 2 and windboxes 19, 20 and 21 beneath strand 2 and in vertical alignment with the chambers 15, 16 and 17, respectively. A feed hopper assembly 22 having three feed chambers 22a, 22b and 22c, is provided for feeding three particle size fractions of shale rock on upper strand 2 to provide a three layer bed of material thereon. A combustion chamber 25 is provided remote from strand 2 and housing assembly 5. An oil separator station is indicated at 30, which may be one or more mechanical oil-gas separators, with or without gas coolers as desired. The oil-gas separating operation is also located apart from the strand 2 and housing 5. Separators suitable for the use that will be described are known to this art and an example of a patent disclosing such a device is U.S. 2,386,196 of 1945.

A gas stream conveying system connects the grate assembly 1, the combustion chamber 25 and the separator 30, in a manner that will now be described. The gas stream conveying system includes a blower 40 and a first conduit 41 for delivering gas to windbox 21. A second conduit 42 with a blower 43 is provided for delivering preheated gas to combustion chamber 25. Gas flow com-

munication from the first conduit 41 to the second conduit 42 is by a path established through windbox 21 and material on strand 2 in chamber 17. A gas stream passing from conduit 41 through material on strand 2 to conduit 42 thereby cools the material and is itself preheated before entering combustion chamber 25.

A third conduit 44 is connected to combustion chamber 25 for delivery thereto of combustion air. Means for controlling the combustion air admitted to chamber 25 is indicated by the valve 45. A fourth conduit 46 is connected to combustion chamber 25 to exit an oxygen free mixture of combustion products and noncondensable combustible gases and deliver such gases to the retorting chamber 16. The gas discharged by conduit 44 to chamber 16 passes downward through material on strand 2 in chamber 16. A fifth conduit 47 is connected to windbox 20 to provide an exit therefrom and establish gas flow communication from the fourth conduit 46 through the upper strand 2 of the grate assembly 1 to the fifth conduit 47. A blower 48 is provided in conduit 47 to blow gases from windbox 20 into windbox 19 and up through strand 2 and into chamber 15. A sixth conduit 49 is connected to chamber 15 and to the oil separator 30. A blower 50 is provided in conduit 49 to deliver to the separator 30 liquid oil (mist) and a stream of noncondensable combustible oxygen free gases educted from the shale. The stream of gases passing out of chamber 16 through windbox 20 and conduit 47 is of greater quantity than the quantity of the gas stream passing into chamber 16 from conduit 46. This is true of course because as the heated gas stream passes through the shale, vaporized oil and noncondensable gases are educted from the shale and added to the gas stream.

Liquid oil from the shale separated from noncondensable gases at 30 may be discharged through an exit at 51 and led off to oil refining apparatus (not shown). The stream of noncondensable combustible gases from the separator at 30 may be discharged through an exit at 52 to a seventh conduit 54 which is connected to the first described conduit 41. Thus the stream of noncondensable combustible gases educted from the shale supplies the need for an oxygen free nonburning gas stream to cool the shale material in chamber 17 and the need (after being preheated and mixed with combustion air from conduit 44) for a burning stream of gases for heating the shale material in the retorting zone 16. An eighth conduit 55 is connected on one end to separator gas exit 52 to deliver some of the gas from separator 30 to combustion chamber 25 without passing through material on strand 2. Means for controlling this flow is indicated by the valve 56.

Because burning fuel in combustion chamber 25 and heating the shale in retorting chamber 16 generates additional volumes of gases which are continuously added to the system, a bleed off will be necessary and may be provided as at 57.

To operate an apparatus such as shown in the drawing and apply thereto the method of operation of the present invention, shale rock that has been crushed and screened to pieces smaller than about one inch but not smaller than 5/8 inch, are charged to a feed hopper chamber 22a. The feed hopper 22 discharges this size fraction of crushed shale on top of the upper strand 2 of the grate assembly 1 which is driven by means (not shown) to move the grate in the direction shown by arrows. Shale rock crushed and screened to pieces smaller than about 5/8 inch but not smaller than about 1/4 inch, are charged to feed hopper chamber 22b which discharges this size fraction as a second layer upon strand 2. The third size fraction of shale rock, crushed and screened to pieces smaller than about 1 1/2 inch but not smaller than about 1 inch, is charged to feed hopper chamber 22c which discharges this large size fraction as the third and top layer of what is then a three layer bed on strand 2. The grate 1 carries the bed of shale through the chambers 15, 16

and 17, which in the practice of this embodiment of the invention define a downstream material flow sequence comprising a shale preheating and oil condensing zone (in chamber 15); a retorting and oil educting zone (in chamber 16); and, a cooling zone (in chamber 17).

After the shale material has given up oil as a vapor and noncondensable gases while in chamber 16 the residue is moved through the cooling zone in chamber 17 where gas from separator 30 at perhaps 100° F. is blown by blower 40 through the first conduit 41 upwardly through windbox 21, strand 2, and into cooling chamber 17, to cool the material thereon to a temperature for handling by rubber conveyor belts or the like, and preheat the gas to perhaps about 860° F. The preheated gas passes from chamber 17 into conduit 42. This preheated air is then drawn in by blower 43 and delivered to combustion chamber 25 where controlled amounts of combustion air from conduit 44 and gases from conduit 55 mix therewith to burn a portion of the combustibles therein. Valve 45 controls the air flow through conduit 44 and provides a primary control to cause sufficient combustion of gases from conduit 42 to occur to provide a mixture of unburned noncondensable gases and combustion products, free of oxygen, to exit from combustion chamber 25 through conduit 46 at about 1200° to 1600° F. Conduit 46 delivers these gases to the retorting chamber 16. Valve 56 provides additional control of the combustion taking place in chamber 25. These gases from conduit 46 pass downwardly through the shale on strand 2 in chamber 16 and heat the shale to at least slightly above oil educting temperature which may be expected to be about 800° F. The gases drawn from windbox 20 at slightly above educting, condensing temperature are blown through conduit 47, windbox 19, and through the shale on strand 2 in chamber 15. The condensable vaporized oil and noncondensable gases educted from the shale in the retorting chamber 16, along with the hot gases from conduit 46, are passed through the bed of shale in chamber 15 which condenses the oil vapors to a stable mist while preheating raw shale from hopper 22. Oil mist and a stream of noncondensable combustible gases exit from chamber 15 through conduit 49 at about 250° F. and are delivered to the mechanical oil-gas separating station 30. Multistage separating, perhaps including or resulting in further cooling, may provide gases in conduits 54-41 and 55-44 at about 100° F.

With the described apparatus as an example of an apparatus that can be operated according to the method of the present invention and the operation that has been described, the gases, which enter chamber 16 at 1200° to 1600° F. and have the greatest potential for educting oil, make first contact with the largest and most difficult to process particles. With this arrangement this gas stream with its very high temperature, which is desired to maximize the eduction of oil from the large particles, is nevertheless, shielded from direct contact with the smallest particles by the protective cover of the top layer of the largest particles. After the top layer of the largest particles is heated and before the heating gases pass on into the second layer of smallest size particles, the heating gases will be considerably lowered in temperature and the possibility of the smallest size particles adhering and destroying the gas permeability of the bed is greatly reduced. As the gases continue through the bed in chamber 16, they pass from the second to the third layer in the bed and the larger (i.e., intermediate) size pieces in this third layer block passage of the smaller pieces from the middle layer, and greatly reduce the possibility that the gases will blow the smallest pieces through the grate or cause them to plug the grate.

From the foregoing detailed description an apparatus and operation according to a process of the present invention, it has been shown how the objects of the invention have been attained in a preferred manner. However modifications to (for example, described tempera-

ture ranges) and equivalents of the disclosed concepts such as readily occur to those skilled in the art are intended to be included within the scope of this invention. Thus, the scope of this invention is intended to be limited solely by the scope of the claims such as are or may hereafter be appended hereto.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method of retorting a plurality of size particles of oil bearing shale segregated into at least three portions which relative thereto contain small, large and intermediate size particles, to recover oil from said particles, comprising the steps of:

(A) charging the three portions of particles to form a burden on a horizontal traveling grate with each portion forming one of three horizontal layers and with said small particle portion occupying a middle layer between upper and lower layers of the particles;

(B) moving the grate with the burden in a path defining a downstream direction and through at least a material preheating and oil condensing zone, a retorting zone for educting condensable vaporized oil and a combustible stream of noncondensable gases, and a cooling zone;

(C) passing a stream of gases which are noncondensable combustible oxygen free gases educted from the material in the retorting zone through a portion of the burden and preheat the stream of gases;

(D) mixing combustion air with the preheated stream of gases which are noncondensable combustible gases educted from material in said retorting zone to provide a mixture thereof and ignite and burn at least part of the combustibles therein in a chamber remote from the retorting zone to provide a stream of heated oxygen free combustion gases;

(E) passing the heated oxygen free stream of combustion gases transversely through the burden in the retorting zone in a path that delivers these heated gases to said burden to make first contact with the layer thereof formed by the large particle portion and then pass through the middle layer formed by the small particle portion and thereafter pass through the layer formed by the intermediate size particle portion to elevate the temperature of the entire burden to an oil and gas educting temperature to drive

off from the burden material vaporized oil and additional quantities of the oxygen free noncondensable combustible stream of gases;

(F) passing the gas stream containing the educted vaporized oil and oxygen free noncondensable combustible stream of gases through the burden in the preheating and condensing zone to preheat the burden material and cool the vaporized oil to condensing temperature to condense educted vaporized oil to a mist;

(G) separating the oil mist from the oxygen free noncondensable combustible stream of gases; and

(H) conducting the stream of gases, from which the oil mist has been separated, to the cooling zone for passing through burden in the cooling zone to cool the burden in cooling zone and provide a supply of the preheated oxygen free noncondensable combustible stream of gases as hereinbefore set forth in step C of this claim.

2. In a method according to claim 1, delivering said portions of said particles to said grate with said small particle portion containing particles larger than approximately $\frac{1}{4}$ inch and smaller than approximately $\frac{5}{8}$ inch, said large particle portion containing particles larger than approximately 1 inch and smaller than approximately $1\frac{1}{2}$ inch, and said intermediate particle portion containing particles larger than approximately $\frac{5}{8}$ inch and smaller than approximately 1 inch.

3. In a method according to claim 1, arranging said intermediate size particle portion in a layer beneath said middle layer, said large particle portion on top of said middle layer, and directing said transverse flow of heated gases downwardly through the burden on said grate in said retorting zone.

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DANIEL E. WYMAN, Primary Examiner

P. E. KONOPKA, Assistant Examiner

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